Use of computer simulation to facilitate observer studies in CT optimisation – a pilot study

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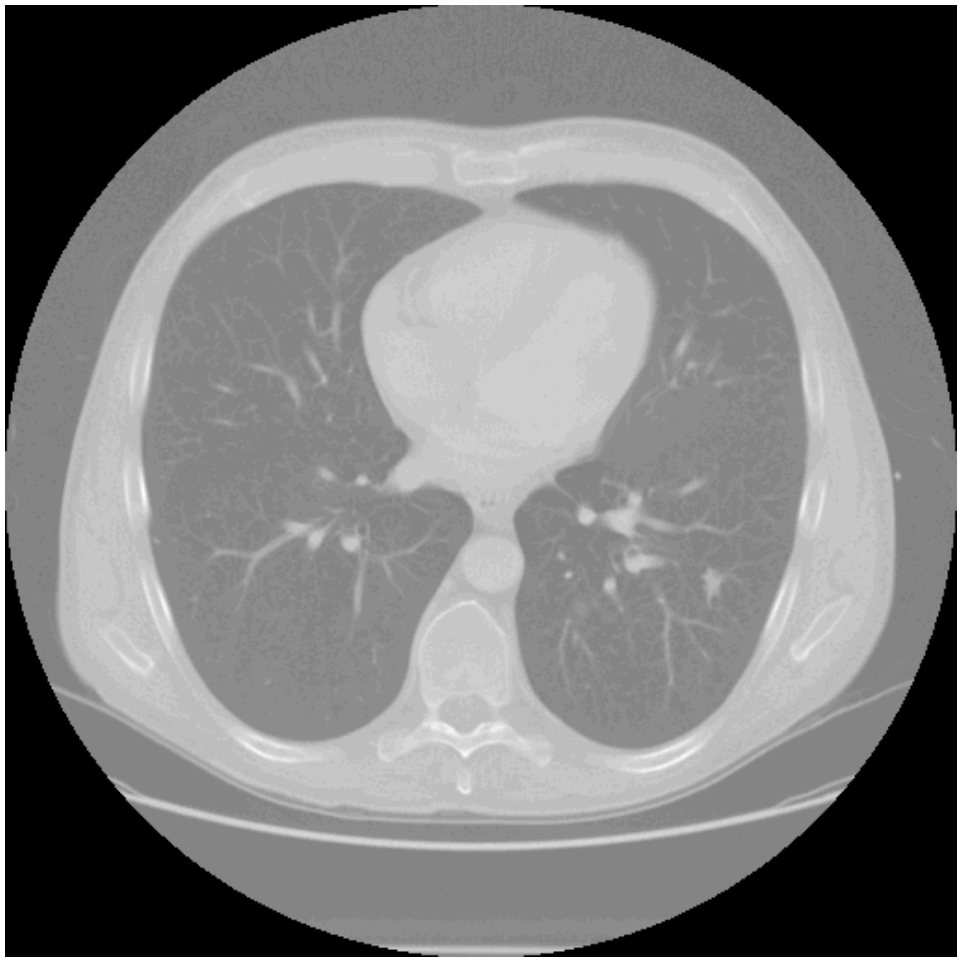
Outline

- Why on earth we did it
- What we did
- What we found

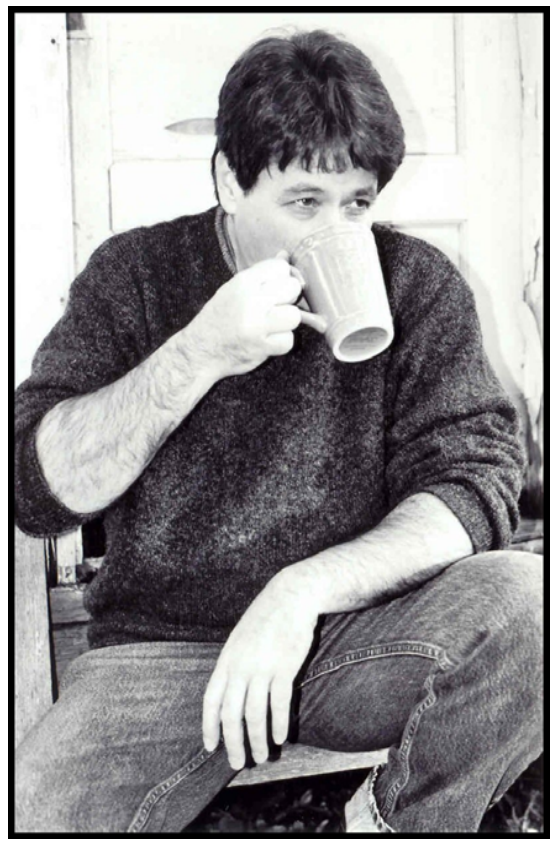


Why did we do this?

- University requires projects for its students
- Students do it for free!
- Can we really do outcome (ish) based optimisation?
  - we have the patients/images [PACS]
  - do we have the time? [we have plenty SpR's]
  - do we have the expertise/tools?
  - can we get a meaningful result?
- Is it worth continuing with these studies?

What did we do?

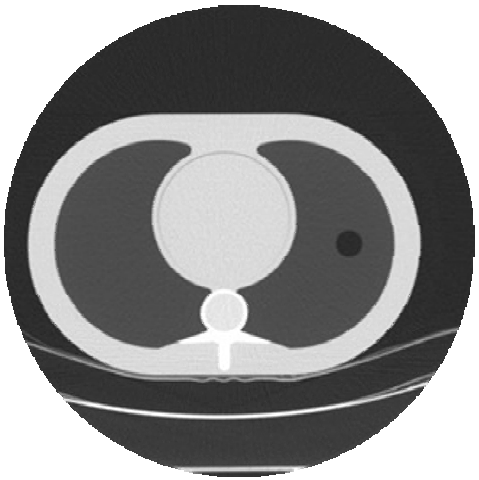
- characterise the CT noise (to enable dose reduction simulation
- retrieve from PACS normal and abnormal CT chests to construct image dataset
- undertake JAFROC with SpR's (streetspeak for 'observer study')



Noise Characterisation

- simulate dose reduction by addition of noise
- CT noise is correlated – characterised by method of Britten et al (BJR 2004 77 323)
  - calculate auto-correlation function
    - symmetric about centre
    - invariant with dose
    - drops to zero 2 pixels from centre (to 3 decimal places)
    - normalise so does not change mean pixel values
  - measure noise as function dose with/without ACF filtering to get 'noise correction' factor (CF)
- use ACF & CF to add 'real' noise for dose reduced images & compare to real scans

Noise Characterisation



Left – thorax phantom

Bottom (L to R)

-real 10 mAs scan

-simulated 10 mAs scan from 20 mAs scan

-simulated 10 mAs scan from 440 mAs scan

LIMIT COMPUTER SIMULATED DOSE TO 50% REAL DOSE

The clinical dataset

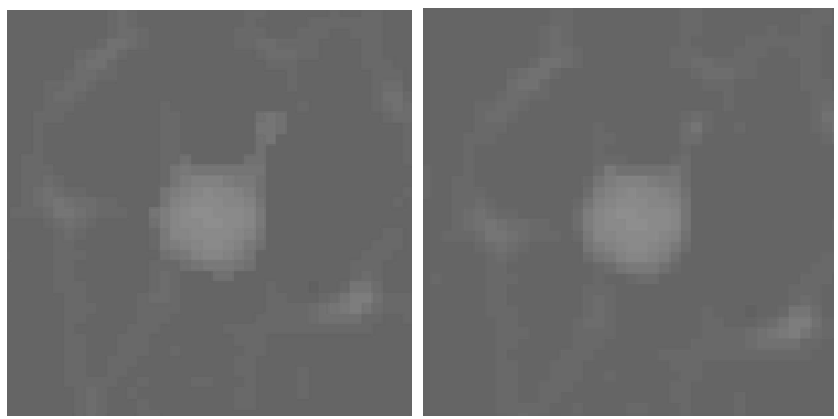
- normal CT slices taken as background for all images
- nodules (varying sizes) added to this background, needed ‘smoothing’ in – extracted from other CT patients
- chosen by experienced radiologist (no ‘gold’ standard)
- final dataset – 20 unique slices, 5 normal 15 with added nodules (1-3 nodules, total n=32)

The clinical dataset

- Noise added such that:
  - 4/20 corresponded to 100% dose (130 mAs)
  - 8/20 corresponded to 75% dose
  - 8/20 corresponded to 50% dose (65 mAs)

Left – unblended added nodule

Right – blended added nodule

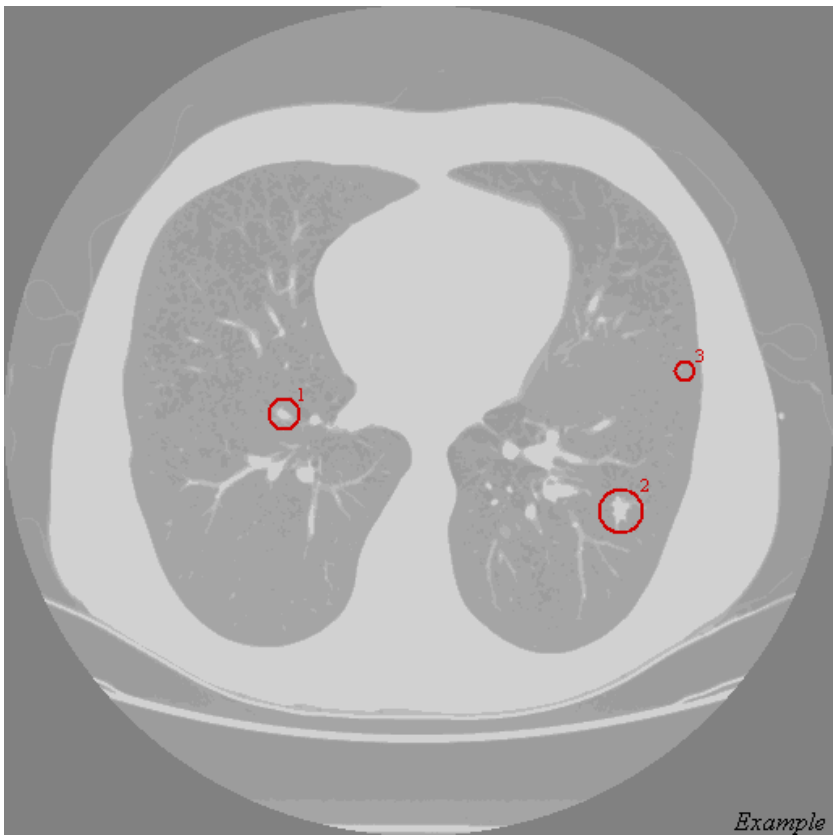


The Observer Experiment

- Images placed on CT workstation
- Scored by 10 radiologists
- Time/radiologist
- Template score sheet with images to annotate
- Allowed to manipulate

Confidence Level	Definition
4	Certainly a nodule/Very Confident
3	Probably a nodule/Confident
2	Possibly a nodule/Fairly Confident
1	Could be a nodule/Not Very Confident

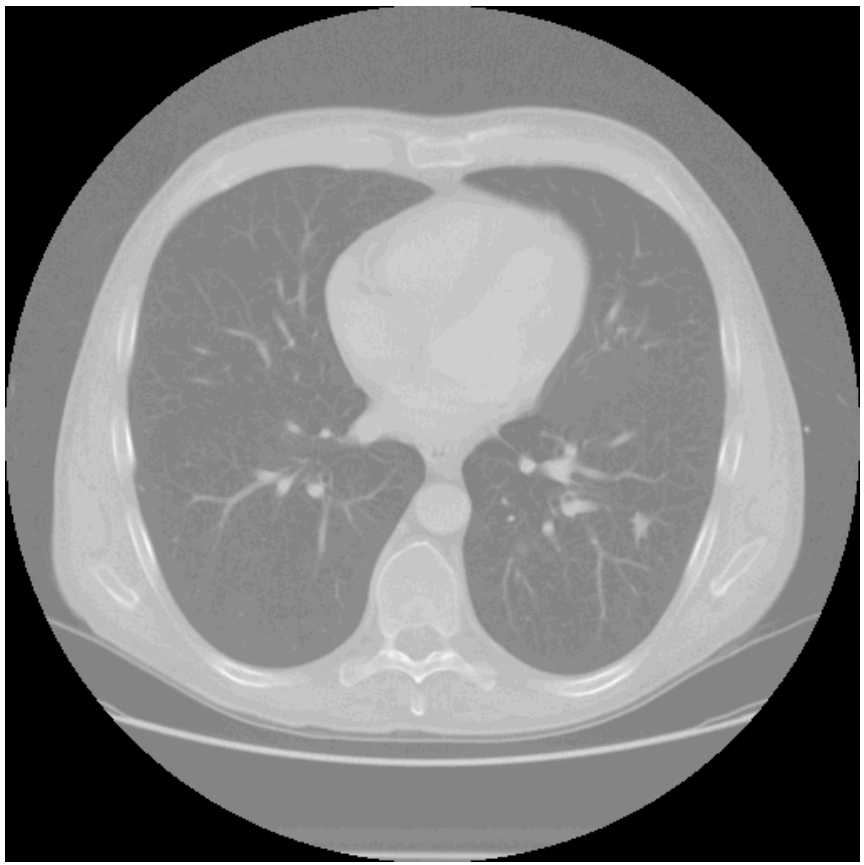
The Score Sheet

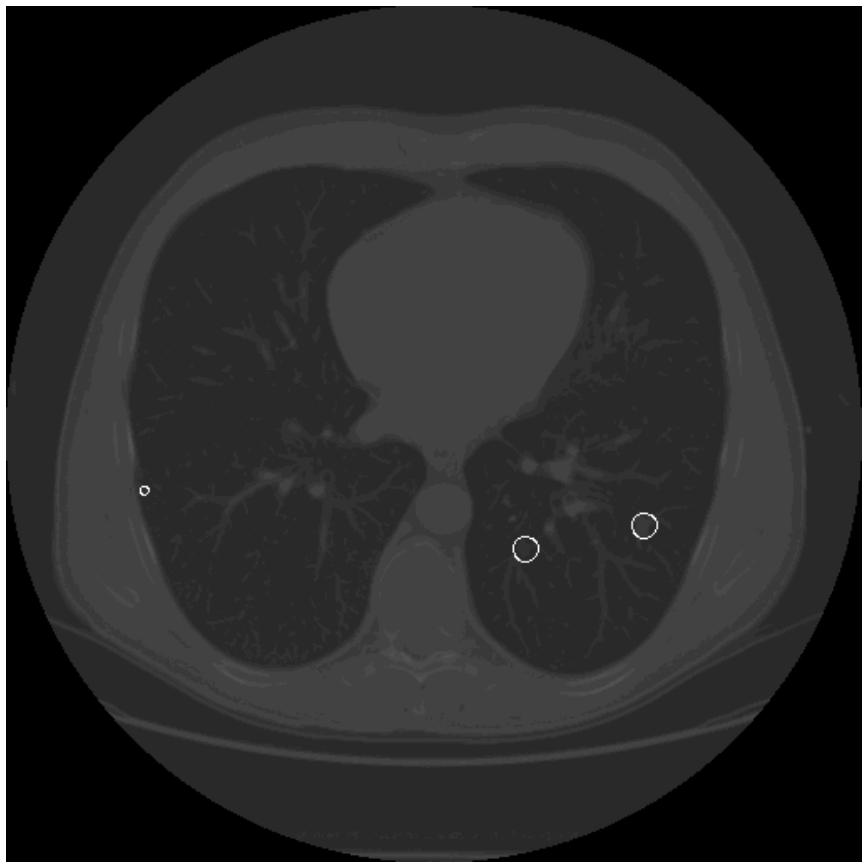


Each scorer had a sheet for each image – yes, they were warned to diagnose from the CT workstation, NOT the score sheet!!

Are there nodules present? (Y/N)	Confidence Level	Nodule Number(s)
Yes	4	2
	3	-
	2	1, 3
	1	-

Sample Images





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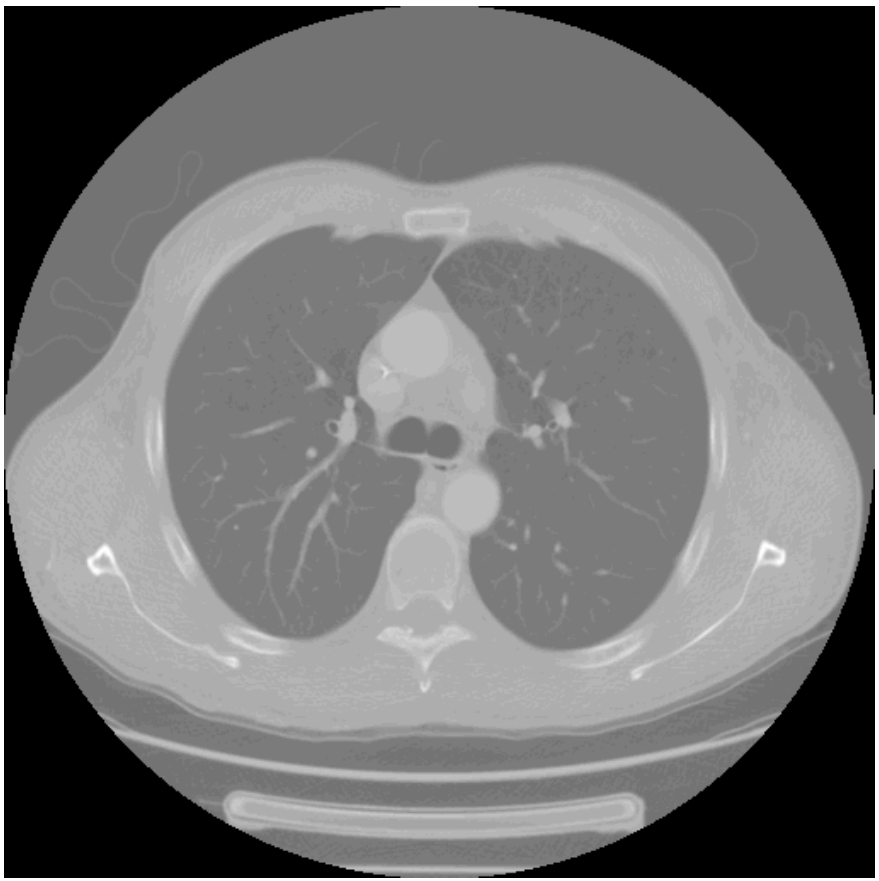
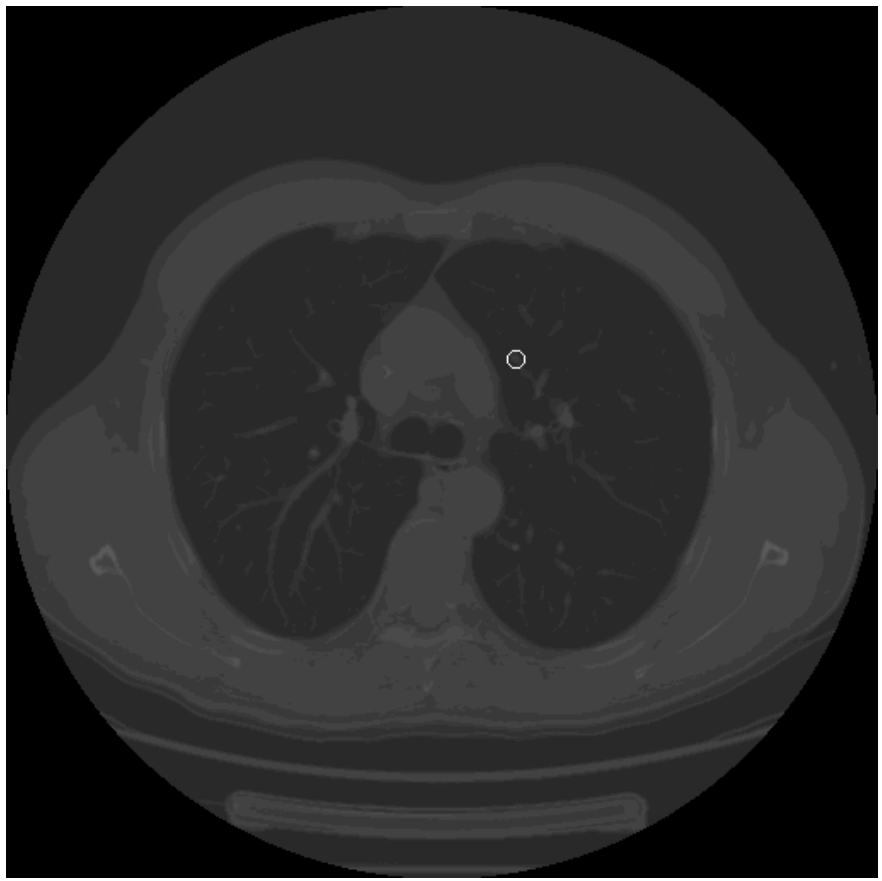
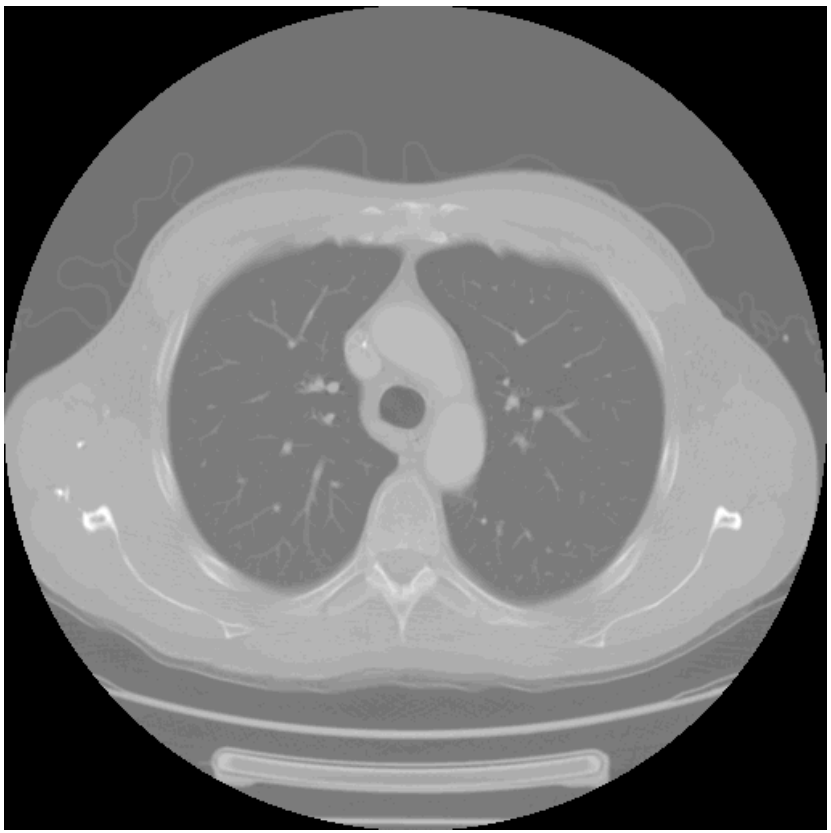
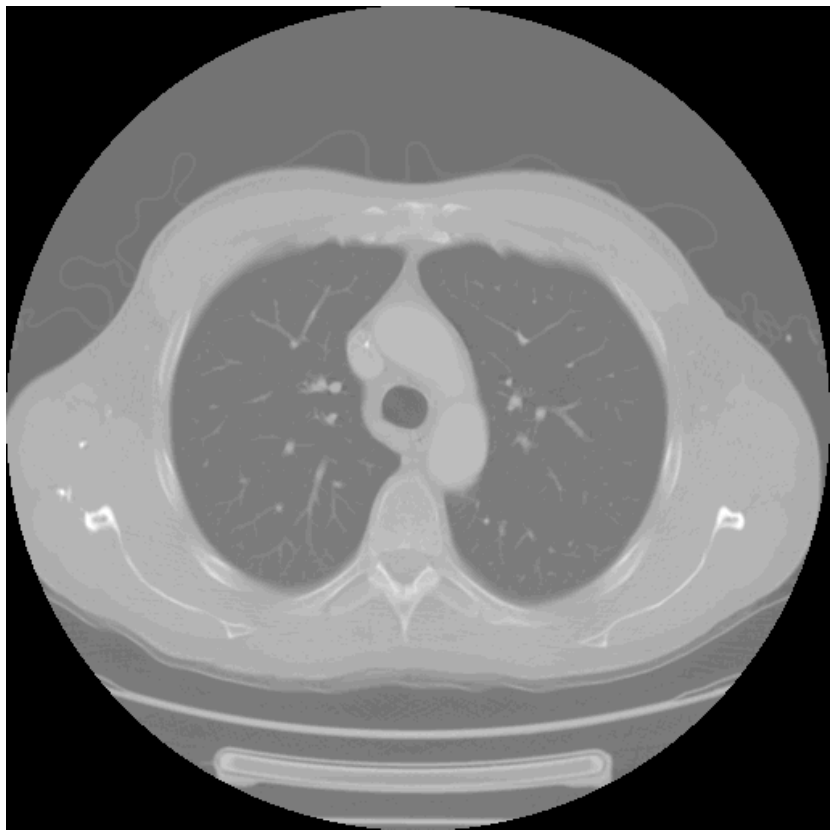




Sample Images

Where is the lesion on the left image?





The analysis

- do JAFROC on image sub-sets – get index [0 – 1, based upon NOT finding FPs]
- do ANOVA on figures of merit for all radiologists by dose
- see if significant differences – YES
- do Wilcoxon-Mann-Whitney on pairs of dose results (e.g. 100% v. 75%)
- looks like see significant difference between the 75% & 50% levels – could this indicate ‘threshold dose’ for optimisation?

The Cock-Up!

- The 50% dose scored the highest radiologist confidences.
- Why:
  - students told that radiologists soon ‘recognise’ patients, so:
    - they made all slices in dataset unique
    - 50% dose examples probably had easier nodules
  - should have had 100%, 75% & 50% for all distinct clinical examples
  - uniform background would hopefully have overcome this potential bias assuming enough slices

The Real Lessons

- Require ‘stack’ of uniform background slices to add nodules into – replicate normal clinical scoring environment
- Ensure larger nodules exist in >1 neighbouring slice
- The method does seem feasible
- But care required in ensuring have multiple dose-levels for each clinical example WITHOUT introducing observer learning bias

The Real Work

- validate the nodule extraction/placement processes
- firm up limits of dose reduction proportion via noise addition
- use data to estimate # patients required for meaningful clinical optimisation
- if too large for one centre, create network of partners
- GO FOR IT!

Acknowledgements

- Kate Pointon, Consultant Radiologist
- The Radiology SpR's whose arms are still strapped up
- Dev Chakraborty for JAFROC software

I would also like to acknowledge that Sherwood FC Girls U9 will become the best team in Nottinghamshire!